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ARTICLE

# Science and Disaster Reduction

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**Abstract** A serious gap exists between science and disaster decision making, so that many scientific reports have little impact and fail to inform decision making. This article examines the complex linkages between science and disaster reduction, analyzing the barriers that prevent more effective use of science and suggesting how the gap between science and decision making may be narrowed.

**Keywords** decision making, disasters, risk assessment, science

## 1 Introduction

It is widely recognized that a serious gap exists between science and expert assessment on the one hand and decision making on the other. Major scientific reports relevant to decision makers frequently pass unnoticed and decision makers remain largely unaware that scientific analyses have been conducted that may be highly relevant to their decision-making areas of responsibility. Decision makers often do not read scientific journals or academic books that regularly appear in their fields of interest, but there is substantial variability in this—between different issues of concern and among different countries.

The notion that a linear process exists between science and policy still permeates the thinking of many scientists and decision makers, and so it is scientists operating in the realm of traditional science who largely determine how problems of science are defined, framed, and communicated to potential users. Predictably, this mode of framing the development of science addresses the need for greater scientific understanding within the scientific community rather than the needs of practitioners in their everyday decisions. In both the halls of science and even within governmental agencies, the goal is assumed to be the growth of scientific understanding of some issue of environment or science and then "outreach," often by posting results on a website, to prospective users. It is also commonplace that prospective users and decision makers do not follow scientific development on websites, so subsequently running through the motions of "outreach" rarely accomplishes the task of transmitting scientific results to those who could use them to inform decision making.

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But the problems go well beyond the issues of effective dissemination and outreach. Political decisions, it has been widely noted, extend well beyond issues of science (Jasanoff 1990; NRC 2009a). Inevitably, a host of other issues—cost and benefit considerations, impacts on industry, reduction of risk achieved, stakeholder views, distributional issues—enter into such decisions. If scientific and assessment studies encompass only the issues of science, they have limited value to prospective users who require a much broader range of considerations and knowledge. As a result, scientific results and assessments of risk and disasters are often not used because they have been defined and framed to meet the needs of science rather than the needs of those making decisions. To avert these problems, a different kind of scientific and assessment process is needed, one that begins with user needs and a problem-solving orientation (NRC 2009a). The communication among scientists, assessors, and users has greatest success when "inreach" as well as "outreach" is involved (NRC 2009b). Effective linkage between science and practice occurs not in a linear process of producers and consumers, but in a continuing two-way interaction in which learning occurs among both the scientists and assessors on the one hand and the practitioners who make decisions on the other, with a rich pattern of feedbacks the norm for both.

## 2 Natural Disasters: A Continuing Toll

The International Strategy for Disaster Reduction was launched in 2000 as a global strategy to build across the international system "a culture of prevention" in multiple societies as part of a global effort to promote sustainable development. The Hyogo Framework for Action 2005-2015 was adopted to achieve this general goal at multiple scales—global, national, regional, and local. The Global Platform for Disaster Risk Reduction was adopted as the global forum to build the resilience of nations and communities for anticipating and coping with disasters.

Despite these laudable efforts, the track record continues to show unrelenting problems. As Munich Re (Munich Reinsurance Company, one of the world's leading reinsurers) data show, while loss of life from natural disasters continues to decline, economic damages worldwide continue to grow. The first decade of the twenty-first century has experienced some of the major disasters of the past 100 years. These have included typhoons in Asia, several major earthquakes in China, a devastating earthquake in Haiti, one of the world's poorest countries, and an environmental catastrophe from an oil spill in the United States, one of the world's richest countries. These events have demonstrated convincingly that despite major planning and financial investments across the globe, disaster risks continue to grow. This trend inevitably raises the question—is this a failing of science, a failure to incorporate science into decision-making, or a product of both?

## 3 Bridges and Spiderwebs

Language pervasively influences our thinking on problems and decision issues. This is pronounced in the case of linkage between science and practice. Rhetoric and writings are replete with references to the "bridge," "superhighway," and "pipeline" that connect science to practice. But it is abundantly clear that the linkage is anything but linear. First, it is clear that a wide cast of intermediaries, including corporate officials, federal agency personnel, state and local officials, and NGO leaders interpret and reframe the results of science for a broad host of decision makers (Moser and Dilling 2007). They do this, as pointed out in writings on the social amplification of risk (see, in particular, Pidgeon, Kasperson, and Slovic 2003), by emphasizing particular elements of the risk results and reframing the basic message of the inference to be drawn for risk and environmental management. A wide variety of stakeholders and actors compete in this arena for shaping the risk and other "signals" to decision makers (Pidgeon, Kasperson, and Slovic 2003). The net effect is to reframe the message and thereby "amplify" or "attenuate" the signal to society and decision makers of the social meaning of the risk event or research.

Accordingly, language is needed that more accurately describes the linkage between science and practice. The author proposes the use of the term "spiderwebs" as a more accurate description of what actually occurs in at least the controversial disasters that become a matter of dispute and controversy. The image of a spiderweb is, of course, an imperfect image of a complex and often unstable network. Technically, the image of a "communal spiderweb" is preferable, with multiple spiders and a dynamic web of linkages. To provide a visual image of such a spiderweb, Figure 1 shows a hypothetical case of a linkage system, a spiderweb, between sciences and practice. This figure suggests a wide range of intermediaries who may be involved—the media, lobbyists, bloggers, NGOs, industry trade groups, and policy brokers. For the purpose of this discussion, science is treated as unitary, which of course it is not. A spectrum of decision makers is typically involved, ranging over public and private institutions, officials at different government scales, individual resource managers, and individual interest groups and decision makers.

Of course, there is no one model or image of the linkage system. But there are at least three major types of architecture to these spiderwebs. The first is the simple spiderweb, in which there is a high degree of direct linkage between science and the primary decision makers. The Intergovernmental Panel on Climate Change is a good illustration of this type of architecture. Here, national governments suggest the members who will serve on the panel and participate in the final stage of report drafting in determining the actual language to be incorporated in the final text. The underlying issue—global climate change—is also an issue that requires involvement and consent by at least the major actors who are involved. The second type of spiderweb architecture is the complex but stable spiderweb. These spiderwebs show a more complex set of actors and less direct linkage between science and end users and decision makers. An example of this type of architecture is the nuclear proliferation treaty, in which there is a stable negotiating and regulatory institution—the International Atomic Energy Agency—but a complex problem area (ability to make and deliver a nuclear weapon) and shifting national agendas and relationships. The structure of political interactions has some relatively stable power relationships and interests, but long-term technical and political uncertainties. The third type of spiderweb architecture is the complex, unstable spiderweb. Here the problem arena is complex, with interests, agenda, and actors that are often unstable. Network actors enter and drop out of the web from time to time. A notable example of this spiderweb architecture is the case of marine fisheries, with diffuse actors facing a rapidly deteriorating risk situation, a weak and unstable regulatory structure, and conflicting national priorities.

Running through these different architectures are several important risk management challenges. How to build and maintain social trust across the diverse actors in the spiderweb is a major need in producing an effective relationship between science and practice (Cvetkovich and Löfstedt 1999; Hardin 2006; Siegrist, Earle, and Gutscher 2007). If the spiderweb becomes more diffuse and contentious, as amplification and attenuation agents compete for control over the framing of the science results and the associated signals of the attached social meaning to society and decision makers, concerted action and "best" practices become more difficult to obtain.

## 4 Boundary Organizations

One major hypothesis has emerged to suggest how the gap between science and practice may be effectively narrowed. Organizations that sit astride the domains of research and user communities, it is argued, assure a greater potential for effective interaction and the production of knowledge more germane to the needs of decision makers. While the range of supporting empirical studies is thin and largely oriented to unitary decision makers in the Western context and to

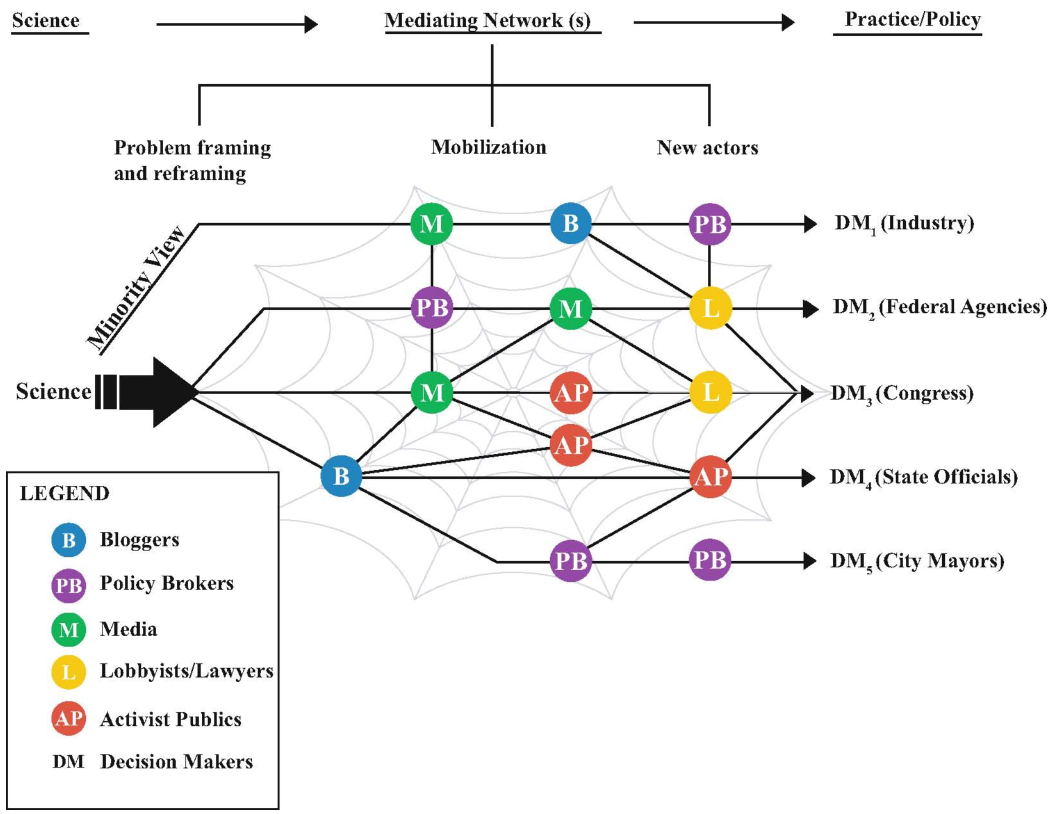


**Figure 1. Schematic diagram of a spiderweb in decision processes and public policies**

international governance regimes based on Western governance notions, several important generalizations have emerged. Boundary organizations are most effective, studies contend (for example, Hellstrom and Jacob 2003), when:

(1) they are situated at the frontier between science and politics, but have neutral accountability to each;
(2) actors from both science and politics and intermediaries in the linkage space between them actively participate in interactions through the linkage domain;
(3) they provide opportunities and incentives for the creation of shared instruments (for example, models or research plans) that facilitate collaborations and pursuit of natural interests; and,
(4) they encourage the coproduction of information and analysis on behalf of both science and practice.

A series of case studies has explored the role of boundary organizations in a range of empirical situations (Guston 1999; Agrawala, Broad, and Guston 2001; Cash 2001; Guston 2001; Carr and Wilkinson 2005).

Despite this valuable work, questions remain. Nearly all studies have addressed only one of the three types of spiderweb architecture—namely Type 1, the simple spiderweb, where both the research and practice domains tend to be unitary and connections are more direct and relatively stable. As yet, we have little empirical evidence drawn from more complex and dynamic spiderwebs where intermediaries are contentious, vie for power, and compete to define framings of the science or risk messages. Organizations may not, however, be the critical issue to begin with. What is most important may be the functions that are achieved and the processes that go forth. A formal structure or organization may well be less important than what its participants achieve, mainly efforts involving coproduction of knowledge, agreed-upon mutual accountability, mechanisms for jointly produced planning, analytical methods and models, and an arena for ongoing mediation on issues and objectives. Beyond this, we need to see how these processes can be obtained, and whether boundary organizations can be found or created in the more challenging spiderweb architectures, where actors are more diffuse, decision makers widely distributed, intermediaries shifting and in conflict, and media contribute to amplification and attenuation of the signals to decision makers and society more generally.

One alternative concept, which emphasizes culture and informal processes rather than structure, is the notion of the epistemic community. In his work on the development of a plan to address pollution in the Mediterranean Basin, Haas (1990) charts the evolution of an interactive network of scientists and policy makers in conducting assessments and formulating an integrative science and risk-management policy for the Mediterranean Basin. He calls particular attention to the creation of extensive personal and professional linkages between scientists and practitioners in creating an overall holistic plan for addressing a wide variety of threats to environmental quality in the Basin. While organizational mechanisms evolved to facilitate both scientific assessments and policy deliberations, at base they rested upon the emergence of a knowledge system with a shared conception of problems and goals, levels of personal trust among key actors, and continuing adjudication of the tensions between science and policy. This analysis captures many of the elements involved in the notion of a "boundary organization," but the focus is clearly on the emergence of a common knowledge system, shared goals, and ongoing negotiation in analysis and deliberation (see also Haas, Keohane, and Levy 1993).

## 5 Do We Need a Different Kind of Science

A major suggestion arising over the last decade is that the principal problem in a more effective relationship between science and policy lies primarily in the area of science—that we need a new kind of science to narrow the gap between science and practice. On the eve of the millennium two major events occurred. The first was the publication of a landmark U. S. National Research Council (NRC 1999) report, *Our Common Journey*. This report highlighted the conclusion that "…tensions exist between integrative problem-driven research and research firmly grounded in particular disciplines; and between the quest for generalizable scientific knowledge of sustainability issues and the localized knowledge of environment/society interactions that give rise to these issues and generate the options for dealing with them" (NRC 1999, 10). The National Research Council in a later report (NRC 2009a) identified a number of priority tasks for overcoming this tension:

(1) develop a research framework that integrates global and local perspectives to shape a "place-based" understanding between environment and society;
(2) initiate focused research programs on a small set of understudied questions that are central to a deeper understanding of interactions between science and the environment;
(3) promote better utilization of existing tools and processes for linking knowledge in action in pursuit of a transition to sustainability;
(4) reorganize the program around integrated scientific-societal issues to facilitate cross-cutting research focused on understanding the interactions among the climate, human, and environmental systems and on supporting societal responses to climate change (NRC 2009a, 4); and
(5) a strong underpinning of observations and models is needed, as well as strengthened research across the board—particularly in the human dimensions of global change and in user-driven (applied) research that supports decision making—and increased involvement of stakeholders…" (NRC 2009a, 5).

Such observations are not uncommon. Although it is abundantly clear that science is needed to inform decision making on the environmental challenges that face society, it is still the case across many societies that science is still conceived, and financially supported, as only the natural, medical, and engineering sciences. And so review of report after report in the United States continues the drumbeat for a more integrated concept of science. Meanwhile, the understanding of human interactions with environmental systems continues to lag badly behind what is needed in an adequate knowledge base to inform decisions in both the public and private sectors. These problems are deep-seated and unlikely to change anytime soon. The personnel and expertise in federal agencies and private corporations continue to share a paucity of social and behavioral science expertise involving such fields as psychology, sociology, anthropology, and geography. Only economics among the social sciences has won broad recognition and involvement. Until this long-standing deficit of expertise is rectified, the knowledge base for practice will continue to have serious gaps and deficiencies that will limit the entrance of science into decision making about disasters and other risks.

## 6 Do We Need a Different Kind of Policy and Decision Process

Another view sees the problem as primarily in the decision-making arena. The rational model approach to decision making is often equated to "command-and-control" decisions, following a military model of addressing a problem or threat, conducting scientific assessments delineating the problem and options for dealing with it, and choosing that option which realizes the greatest gain, or utility, in terms of decision maker goals. This approach can be elaborated, though not fundamentally changed, by approaches of multi-objective decision making. Such conceptions rely heavily on assumptions of a unitary decision maker, not a distributed decision system, and requisite knowledge to realize decision objectives. But what do we do when uncertainties are very large, decision goals contested, and decision systems distributed and not unitary? This has led to some changed prescriptive views of policy—for example, that at least for certain kinds of risk decisions, such as those with large uncertainties but large irreversible damage—that precautionary decision making should replace rational, utility maximizing approaches (Harremoës et al. 2002).

For at least certain decision problems for which science is inherently limited in providing the information and analysis needed to reach a traditional "good" rational decision based on strong scientific analysis, other approaches to decision making are receiving growing attention. Among these, recent discussions have taken up adaptive management as an effective, and perhaps preferable, alternative to "command-and-control" management (Holling 1978; Folke et al. 2005; Renn and Walker 2008). Here the argument is for a "go with the flow" kind of decision making, one based on the notion that knowledge is evolutionary and that learning and incremental decision making, if well structured, can produce a more intelligent and successful management system over time. Certainly it can be better adapted to situations of emerging knowledge and large uncertainties than "command-and-control" approaches. Figure 2 shows the major differences in how these two decision processes are structured.

But adaptive management may travel the same course as other corrupted concepts, such as "sustainability." It is now commonplace to hear all managers assert that they enthusiastically embrace adaptive management. Since it is assumed that adaptive management means little more than remaining flexible in the face of changing environmental threats or decision contexts, decision makers all readily claim that they have always embraced adaptive management. After all, who would claim a position of imperviousness to new knowledge, experience, or changing social and political contexts? It is further assumed that one size fits all problems—adaptive management suggests little difference to most decision makers than what they have always done.

A more rigorous embrace of adaptive management, as outlined by serious thinkers such as Holling (1978), Walters (1986), and Lee (1993), suggests something quite different. Decisions are regarded as "experiments" rather than definitive solutions. Learning can be very difficult to achieve because of the tendency of most management systems to exhibit "path dependency" (Brown et al. 2007). Decision makers are prone to embark on a particular management direction or embrace a particular preferred solution, and, as a result, changes in basic thinking or approach become difficult to achieve (Kingdon 1995). Consequently, learning tends to be restricted to low-level learning induced by better data, and not basic rethinking of problems and approaches.

There are institutional impediments as well, and they are more far-reaching and fundamental than is commonly assumed. In essence, they involve a lack of designs and mechanisms not only to encourage flexible management approaches but, more fundamentally, to promote and facilitate social learning from experience. It has been widely noted that managers typically repeat errors rather than learn from them. In adaptation and reconstruction, basic vulnerabilities are often recreated, as the Katrina experience in New Orleans suggests (Kates et al. 2006).

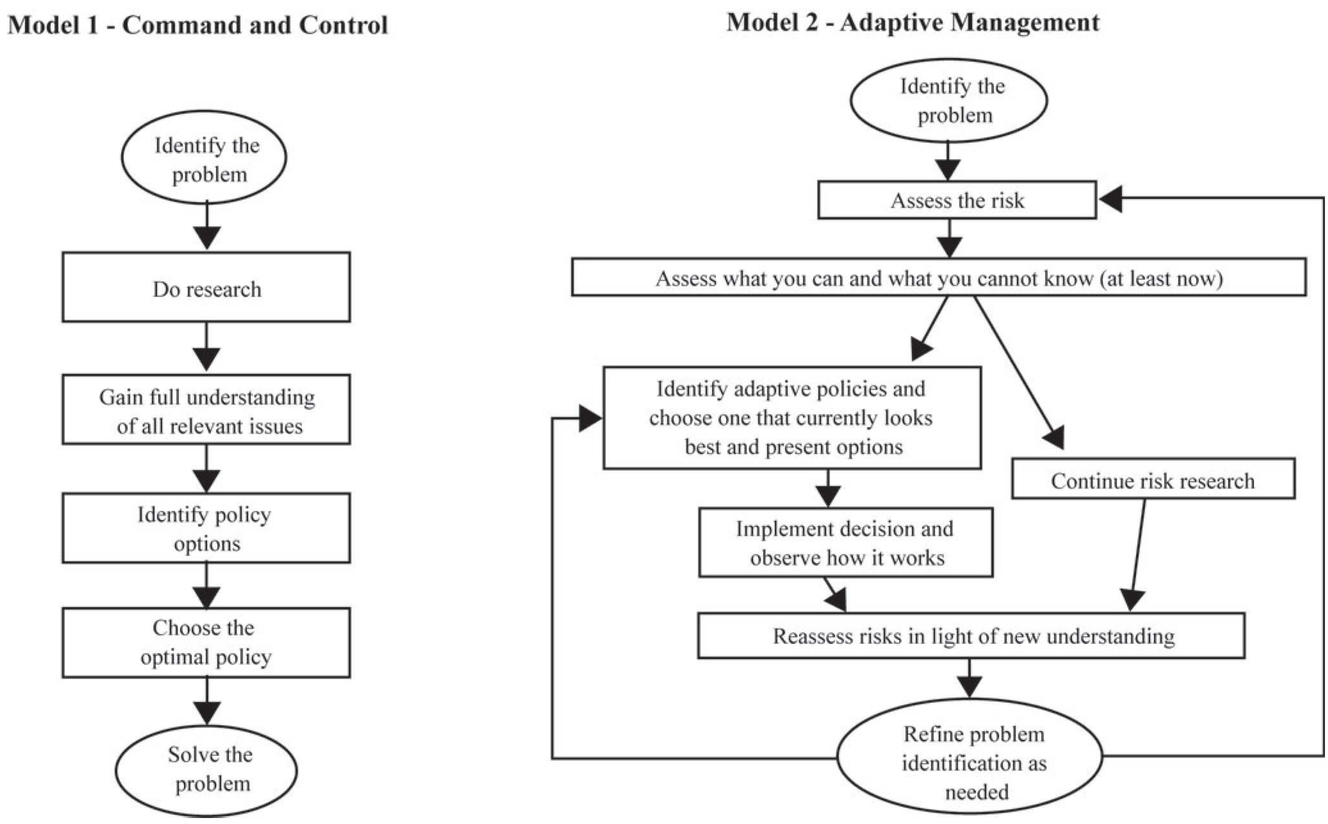


**Figure 2. Models of decision processes in policy making**
Source: After Morgan et al. 2007.

To facilitate social learning from experience and other sources of knowledge, a diversity of inputs to the decision makers needs to be maximized (Social Learning Group 2001). Thus, the boundaries of the agency or organization need to be highly permeable and contrary or contested views not only accepted but actively sought out. The typical approach to critics and opponents of an agency plan is to isolate them as much as possible and to put them at the end in public involvement and communication initiatives. Adaptive management approaches require a major turnaround in these approaches. The strategy needs to engage critics and opponents from the outset. It must be understood that valuable things can be learned from such interactions, perhaps about the nature of the risks and related vulnerabilities, but surely about the issues that developers, regulators, and other decision makers will face across the table in public hearings, and (increasingly) in the courtroom. More importantly, developers and decision makers may come not only to understand better the issues of contention, but also to begin early to explore how opposing views may be negotiated where gaps may exist in the knowledge base assembled for those issues, or whether new monitoring systems may be needed.

But also it is the case that, as technology moves to more mature stages of development, development agencies and corporations will face a broader range of issues associated with vulnerabilities, public concerns, risk communication, and public involvement. Accordingly, a wider range of expertise, which as yet may not have been brought into the decision-making organizations, may be needed.

Yet another issue relates to the management process itself in "go with the flow" adaptive management. This process calls for open acknowledgement of uncertainties that may limit the adoption of particular solutions and frank admission of errors that have occurred in past management choices. Adaptive management assumes evolutionary knowledge about environmental changes and risk (Jasanoff 2004; Lemos and Morehouse 2005). Reacting to this is an evolutionary development of management strategies in which decisions and solutions are incremental. Thus false starts and solutions at one point in time are expected to change and develop. This is in accord with what expertise would suggest. But two points are relevant. First, politically acknowledging uncertainties that are not well understood and errors that have occurred in past management strategies requires a degree of candor and openness that decision makers rarely have, and political prices are to be expected. Second, negative effects on social trust should be anticipated. After all, perceived competence is one of the major dimensions of social trust, and if doubts arise in major stakeholders and the public as to whether managers possess the needed competence and expertise, then erosion of trust in the managers might well be expected. This may well move decision making of all kinds to become more contentious and more conflicted, and threaten greater paralysis and delay than otherwise might occur.

## 7 Responding to the Risk At Hand

The current rush to embrace adaptive management often proceeds with the assumption that "one size fits all." A sound approach to disaster management should begin with an inquiry into the nature of the disaster. "Learning by experience" and "going with the flow" are attractive where uncertainties are especially large and the consequences accumulate over time. This is typically the case for natural disasters or climate change. But for disasters where uncertainties may be more limited and consequences abrupt and potentially catastrophic, a disaster management strategy that proceeds by learning from experience is less appropriate. So distinctions among disasters are essential—what is the nature of the disasters? What consequences to society and ecology may be involved? Learning and flexibility need not be lost but more reliance upon risk analysis may be needed, as informed by both analytical models and experience.

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